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Scheimpflug imaging of the post lens tear film during contact lens wear

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A new imaging methodology is described to visualise the post lens tear film (PLTF) during contact lens wear. A rotating-Scheimpflug camera in combination with sodium fluorescein allows evaluation of the PLTF for different contact lens modalities, including mini-scleral, rigid gas permeable (RGP) and soft contact lenses. This imaging technique provides an extension of the instrument's current functionality. The potential advantages and limitations of the technique are discussed.

Keywords: Contact lenses; Image analysis; Post lens tear film

1. Introduction

The post lens tear film (PLTF) is the tear (or liquid) layer that forms between the corneal epithelium and the posterior surface of a contact lens. The PLTF plays an important role in the maintenance of the health of the anterior eye during contact lens wear including corneal hydration and oxygenation and the turn-over of the PLTF ensures removal of metabolic waste products and debris from behind the lens. During rigid lens wear (RGP or mini-scleral), the PLTF also contributes to the overall refractive power of the contact lens correction and neutralises some anterior corneal astigmatism and aberrations.

In a clinical setting, the PLTF is qualitatively assessed by instilling sodium fluorescein into the conjunctival sac and using a slit-lamp biomicroscope with a cobalt-blue filter. This visualisation provides valuable qualitative information concerning the interaction between the cornea and contact lens and is routinely used to assess the fit of rigid lenses. Unlike rigid lenses, standard sodium fluorescein dye is not typically used to assess the fit of soft contact lenses as the dye is absorbed by the lens and the lens wraps to the underlying cornea resulting in minimal PLTF. However, high-molecular-weight sodium fluorescein, can be used to image the PLTF and is useful when fitting specialised soft contact lenses such as hybrid [1] and micro-channel contact lenses [2].

Although the evaluation of the fluorescein pattern observed using a slit-lamp biomicroscope is the gold clinical standard, it is a subjective assessment of the lens fit providing no quantitative information such as minimum apical clearance. The appearance of the fluorescein pattern may also vary depending on the magnitude and angle of the illumination source and the concentration of fluorescein in the PLTF [3]. Additionally a thin tear layer will not fluoresce enough to be detectable by the human eye [3,4] and may be incorrectly interpreted as corneal touch or bearing. To minimize the subjectivity of the slit-lamp based contact lens examination, a number of authors have proposed rules and guidelines on the assessment of the fluorescein patterns for RGP [5] and mini-scleral lenses [6]. Optical coherence tomography has also been used to aid in the fitting of mini-scleral contact lenses, since instruments with a wide horizontal scanning field can provide useful sagittal height measurements at various corneal and scleral chord diameters [7]. In this paper a method to visualize the PLTF using a rotating-Scheimpflug camera is investigated, including the potential quantification of the PLTF for mini-scleral lenses.

2. Methods

This report evaluates the novel use of a rotating-Scheimpflug camera to image the PLTF for a range of different contact lens modalities including mini-scleral, rigid gas permeable and soft contact lenses. For each lens, a set of measurements with a rotating-Scheimpflug camera (Pentacam HR Oculus, Wetzlar, Germany) were taken using the standard 3D scan mode that consists of 25 pictures (cross sectional images) over the entire cornea. The instrument's illumination, which operates at a wavelength of 475 nm (monochromatic blue light), can be used to enhance the reflectivity of the tear film in combination with sodium fluorescein, in a similar fashion as performed clinically with slit-lamp biomicroscope imaging. Thus, the fluorescein acts as a contrast agent enhancing the visibility of the PLTF.

3. Results

Mini-scleral lenses: A mini-scleral contact lens was inserted into the patient's eye with preservative free saline and sodium fluorescein and was assessed using a slit lamp biomicroscope. In Scheimpflug imaging, due to the large gap between the lens and the corneal surface, as well as the high concentration of fluorescein, the PLTF appears as a distinct hyper-fluorescent white layer in the images. Graph-segmentation methods, previously used to segment OCT images [8] were adapted to extract the anterior and posterior boundaries of the PLTF and to estimate the change in PLTF thickness during the settling period. The pre-lens tear film layer is not visible with this technique since it is thinner than the axial resolution of the instrument (about 20 µm). The pre-lens tear film is about 3 µm thick [9]), whereas the PLTF under the mini-scleral lens that was used in this trial is reported to range from 220 µm up to 650 µm [10].

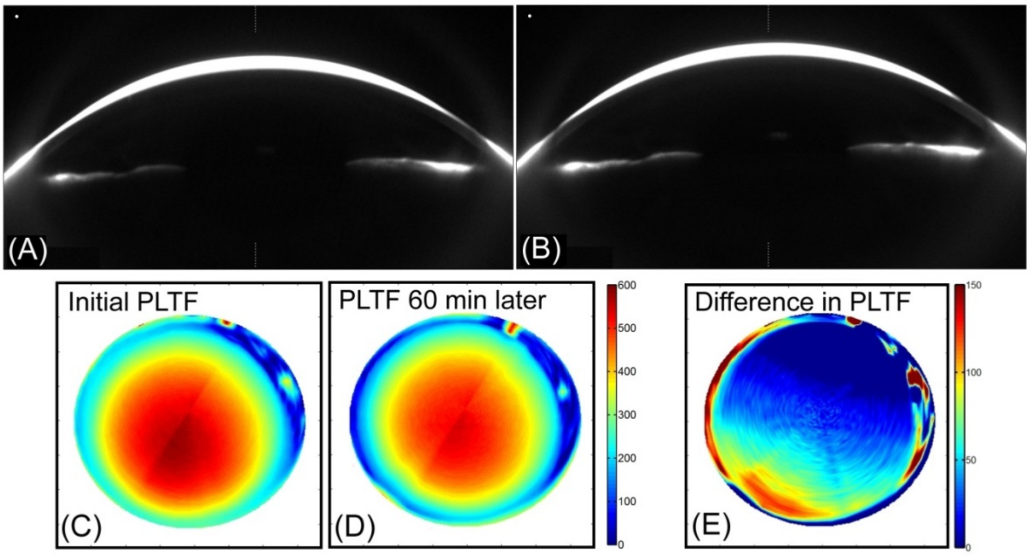

Figure 1 Scheimpflug cross-sectional images showing the PLTF hyper-reflectivity during mini-scleral lens wear, immediately after insertion (A) and one hour after insertion (B). The lower row represents the PLTF thickness maps immediately after insertion (C) and one hour after insertion (D) and the difference map (E).

Scheimpflug images taken immediately after lens insertion (Fig. 1A) and 1 hour after insertion (Fig. 1B) can be used to assess the settling of the lens on the eye as well as to quantify the apical clearance (or corneal vault) of the lens (i.e. the PLTF thickness). The thickness maps after lens insertion (Fig. 1C) and 1 hour after insertion (Fig. 1D) can be used to assess the settling of the lens on the eye, while the difference map (Fig. 1E) indicates that the amount of settling varies across the corneal surface, with the greater changes seen inferiorly.

Rigid gas permeable lenses and soft contact lenses: For these two lens modalities is not possible to quantify the PLTF as the resolution of the images is not sufficient to delineate the two boundaries of the PLTF (typically less than 12 µm). Thus, for these images a qualitative analysis was performed. For each Scheimpflug image, the front surface of the lens was segmented using the graph-segmentation technique then a fixed region of 10 pixels (177 µm) below the anterior surface was cropped. This value ensures that the entire PLTF is encompassed within the region of interest. The cumulated intensity along the axial direction for this region was then extracted. The same analysis was repeated for each of the 25 Scheimpflug images acquired in the radial scan pattern of the rotating camera from which a reconstructed en face Scheimpflug map, which resembles the slit-lamp image, can be created. Figure 2 presents the slit-lamp image, the reconstructed en face Scheimpflug map and a single Scheimpflug image (nasal to temporal cross-section) for an optimally fitted RGP (A-B-C) and inverted -6.00 D soft contact lens (D-E-F) respectively. The inverted soft contact lens does not completely wrap to the underlying cornea so the PLTF is most visible in regions of non-alignment (steep fit). In this figure, it can be appreciated that the en face Scheimpflug images of the PLTF are comparable to the fluorescein patterns observed with slit lamp photography.

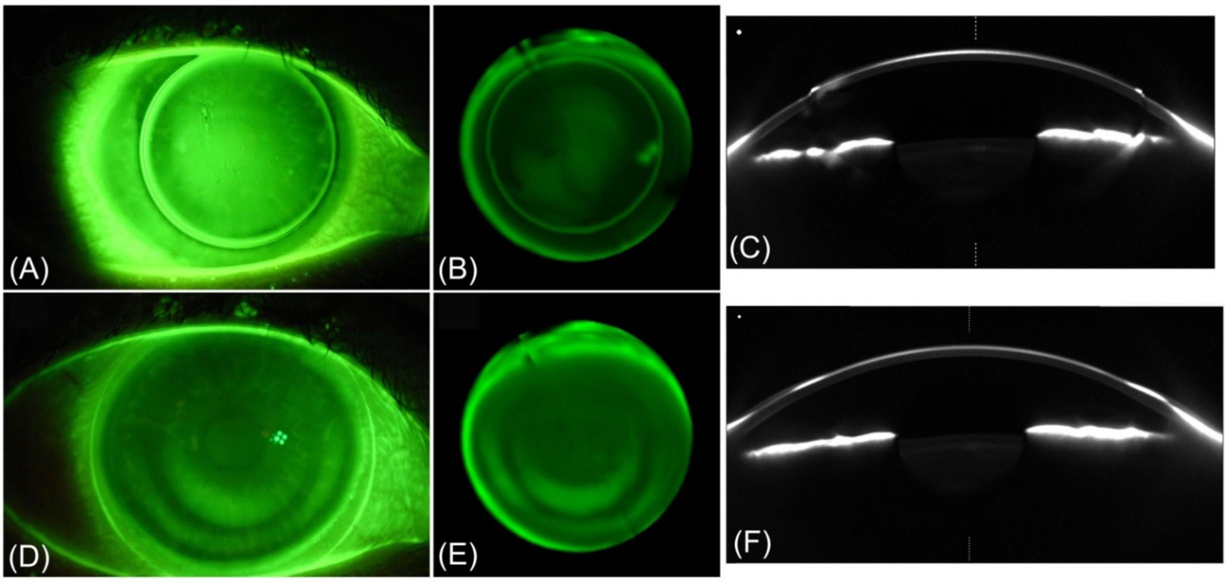

Figure 2. Slit-lamp image, reconstructed en face Scheimpflug map and a single Scheimpflug image (nasal to temporal cross-sectional image) for an optimally-fitted RGP (A-B-C) and inverted soft contact lens (D-E-F).

4. Conclusions

A new imaging methodology to visualise the post lens tear film (PLTF) during contact lens wear was described. This technique requires no additional hardware but software development to provide an extension to the instrument's current functionality. Thus it provides a potential new platform to image and assess the PLTF and to evaluate the cornea and contact lens interaction and aid in determining the fit of a contact lens.

Regarding the assessment of the different contact lens modalities, this method shows promise for imaging mini-scleral lenses since it may allow quantitative assessment of the PLTF over a large corneal area. For soft contact lenses, the method provides a qualitative assessment of the PLTF, which may be of interest for specialized soft contact lens designs. Similarly, the method allows for the qualitative assessment of RGP lens fit. However this qualitative en face image of the PLTF for the soft and RGP lenses offers no significant advantage over traditional slit lamp biomicroscope imaging of fluorescein patterns.

Given that the intensity of the Scheimpflug image is related to the PLTF thickness, it may be of interest to model this relationship. Although to study this model was beyond the scope of this paper, it could be modelled by imaging fluorescein samples of different concentrations and thicknesses, which would allow a better understanding of the resolution and accuracy of Scheimpflug imaging to assess the PLTF.

Even though the Scheimpflug camera acquisition settings are well controlled, the measurement still depends on the fluorescein concentration in the eye and so for repeatable recordings, the fluorescein concentration in the PLTF needs to be constant or if the concentration varies, the time course of this variation needs to quantified. This is a major limitation of the current technique that should be considered and improved upon in future studies.

The assessment of the cornea-contact lens relationship is important to ensure safe wear of optimally fitting contact lenses. The PLTF provides vital clinical information about the contact lens fit, therefore new techniques to quantify this post-lens tear layer are of obvious clinical value. The rotating-Scheimpflug camera offers a novel platform for the imaging of the PLTF, with the potential for application in aiding the assessment of mini-scleral lens fitting.

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